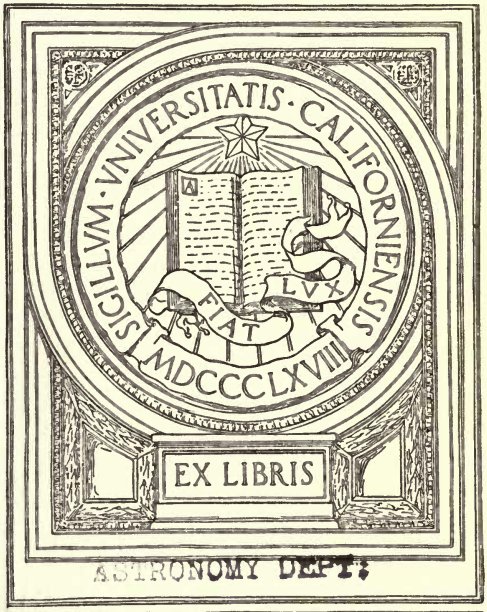
R. T. Crawford

gift of Publishers

4-17-23



HOW TO IDENTIFY THE STARS

THE MACMILLAN COMPANY
NEW YORK · BOSTON · CHICAGO
ATLANTA · SAN FRANCISCO

MACMILLAN & CO., LIMITED
LONDON · BOMBAY · CALCUTTA
MELBOURNE

THE MACMILLAN CO. OF CANADA, LTD.
TORONTO

HOW TO IDENTIFY THE STARS

BY

WILLIS I. MILHAM, PH.D.

FIELD MEMORIAL PROFESSOR OF ASTRONOMY
IN WILLIAMS COLLEGE

New York
THE MACMILLAN COMPANY
1922

Set up and electrotyped. Published June, 1909.

Norwood Press
J. S. Cushing Co. — Berwick & Smith Co.
Norwood, Mass., U.S.A.

CONTENTS

I. INTRODUCTION

THE ability to recognize the more brilliant stars and to locate the more conspicuous constellations or star groups, is both an interesting and a useful acquirement. The number of people who have a real interest in popular astronomy and a fair acquaintance with the stars and constellations is steadily increasing and they find real pleasure in their information. To the meteorologist who would make observations of the position of the streamers of the Aurora Borealis or locate the place of the appearance and disappearance of bright meteors, a knowledge of the stars and constellations is absolutely necessary. The best way to locate the position of an auroral streamer without the use of apparatus is to observe the stars between which and over which it extends. Similarly the point of appearance and disappearance of a meteor has been definitely determined if the nearest star in each case has been noted. If great

exactness is desired, the angular distance and direction of the point in question from the nearest star may be estimated. Whenever an object is thus located by means of the stars, the exact time of observation and the place of observation (latitude, longitude, and elevation) must also be stated. From such observations made at two, preferably more, stations, the distance, height, and direction of an auroral display, and the distance, height, direction of motion, velocity of motion, and orbit in space of a meteor may be determined by computation.

The purpose of the constellation tracings and the descriptive material here given, is to serve as a guide in taking the first steps in learning the stars and constellations and also to point the way to the acquisition of further information on the part of those who desire it. The method here followed and the material presented is essentially the same as that used in the course on Descriptive Astronomy in Williams College.

II. THE HISTORY AND NUMBER OF THE CONSTELLATIONS

THE first definite information concerning the constellations comes from Claudius Ptolemy at the Alexandrian School of Philosophy in about 150 A.D. He was a great systematizer of information and summarized the astronomical learning of his time. His original writings in the Greek are lost, but an Arabic translation of his manuscript on Astronomy, called the "Almagest," has come down to us. In it he enumerates, describes, and locates 48 constellations; 21 northern, 15 southern, and 12 zodiacal. These constellations by no means covered the whole sky, as a large part of the southern hemisphere was not mapped and there were often unmapped spaces between the constellations. As the centuries passed, the need of more constellations became apparent, but it was considered sacrilegious to add to the Ptolemaic list. Finally, in 1601, two constellations were added

by Tycho Brahe. This opened the way, and for two centuries nearly every astronomer of note considered it his duty to map a group of stars and give to the group a name of his own choosing. Thus by 1800 there were at least 109 fairly well known constellations, and a large constellation (Argo) in the southern hemisphere was divided into four, thus making 112. The difficulties were now as great as before new constellations had been added, for some of the constellations overlapped and names had been given to some of them which could never become international. Gradually, by practically common consent, 24 were dropped, so that at present there are 88 constellations. The accompanying list shows the number of constellations added by each astronomer.

140 A.D.	Ptolemy	48
1601	Tycho Brahe	2
1603	Bayer	12
1679	Royer	5
1690	Halley	1
1690	Hevelius	11
1725	Flamsteed	2
1752	La Caille	14
1770	Hell	1
1776	Le Monnier	2
1776	Lalande	1
1777	Poczobut	1
1800	Bode	9
		109
	Argo divided into four parts	3
		112
	Twenty-four were dropped	24
		88

Some authorities attribute one constellation to the Emperor Hadrian in 130 A.D., one to Eratosthenes in 300 A.D., and four to Bartschius in 1624 A.D. and thus a smaller number to some mentioned in the table.

These eighty-eight constellations do not overlap, have definite boundaries, and cover the whole sky. The boundary lines usually wind in and out among the stars and are very irregular, particularly in the case of the

northern constellations. Some of the southern constellations have boundaries which are for considerable distances arcs of great or small circles. The constellations are also of very unequal size, some being ten times as large as others.

The following list contains the names of the constellations, the Latin genitive of the name, the meaning of the name, and the name of the originator of the constellation: —

NAME	GENITIVE	MEANING	PROPOSER
Androm'-eda	Androm'-edæ	Andromeda	Ptolemy
Ant'-lia	Ant'-liæ	Air-pump	La Caille
A'-pus	Ap'-odis	Bird of paradise	Bayer
Aqua'-rius	Aqua'-rii	Water carrier	Ptolemy
A'-quila	A'-quilæ	Eagle	Ptolemy
A'-ra	A'-ræ	Altar	Ptolemy
A'-ries	Ari'-etis	Ram	Ptolemy
Auri'-ga	Auri'-gæ	Charioteer	Ptolemy
Boo'-tes	Boo'-tis	Bootes	Ptolemy
Cæ'-lum	Cæ'-li	Chisel	La Caille
Camelopar'-dalis	Camelopar'-dalis	Giraffe	Hevelius or Bartschius
Can'-cer	Can'-cri	Crab	Ptolemy
Ca'-nes Venat'-ici	Ca'-num Venatico'-rum	Hunting dogs	Hevelius

NAME	GENITIVE	MEANING	PROPOSER
Ca′-nis Ma′-jor	Ca′-nis Majo′-ris	Greater dog	Ptolemy
Ca′-nis Mi′-nor	Ca′-nis Mino′-ris	Lesser dog	Ptolemy
Capricor′-nus	Capricor′-ni	Goat	Ptolemy
Cari′-na	Cari′-næ	Keel	La Caille
Cassiope′-ia	Cassiope′-iæ	Cassiopeia	Ptolemy
Centau′-rus	Centau′-ri	Centaur	Ptolemy
Ce′-pheus	Ce′-phei	Cepheus	Ptolemy
Ce′-tus	Ce′-ti	Whale	Ptolemy
Chamæ′-leon	Chamælon′-tis	Chameleon	Bayer
Cir′-cinus	Cir′-cini	Compasses	La Caille
Colum′-ba	Colum′-bæ	Dove	Royer or Bartschius
Co′-ma Bereni′-ces	Co′-mæ Bereni′-ces	Berenice's hair	Tycho Brahe or Eratosthenes
Coro′-na Austra′-lis	Coro′-næ Austra′-lis	Southern crown	Ptolemy
Coro′-na Borea′-lis	Coro′-næ Borea′-lis	Northern crown	Ptolemy
Cor′-vus	Cor′-vi	Crow	Ptolemy
Cra′-ter	Crate′-ris	Cup	Ptolemy
Crux	Cru′-cis	Cross	Royer
Cyg′-nus	Cyg′-ni	Swan	Ptolemy
Delphi′-nus	Delphi′-ni	Dolphin	Ptolemy
Dora′-do	Dora′-dus	Sword-fish	Bayer
Dra′-co	Draco′-nis	Dragon	Ptolemy
Equu′-leus	Equu′-lei	Little horse	Ptolemy

NAME	GENITIVE	MEANING	PROPOSER
Erid'-anus	Erid'-ani	The river	Ptolemy
For'-nax	Forna'-cis	Furnace	La Caille
Gem'-ini	Gemino'-rum	Twins	Ptolemy
Grus	Gru'-is	Crane	Bayer
Her'-cules	Her'-culis	Hercules	Ptolemy
Horolo'-gium	Horolo'-gii	Clock	La Caille
Hy'-dra	Hy'-dræ	Snake	Ptolemy
Hy'-drus	Hy'-dri	Water snake	Bayer
In'-dus	In'-di	Indian	Bayer
Lacer'-ta	Lacer'-tæ	Lizard	Hevelius
Le'-o	Leo'-nis	Lion	Ptolemy
Le'-o Mi'-nor	Leo'-nis Mino'-ris	Lesser lion	Hevelius
Le'-pus	Lep'-oris	Hare	Ptolemy
Li'-bra	Li'-bræ	Balance	Ptolemy
Lu'-pus	Lu'-pi	Wolf	Ptolemy
Lynx	Lyn'-cis	Lynx	Hevelius
Ly'-ra	Ly'-ræ	Harp	Ptolemy
Ma'-lus	Ma'-li	Mast	La Caille
Men'-sa	Men'-sæ	Table	La Caille
Microsco'-pium	Microsco'-pii	Microscope	La Caille
Monoc'-eros	Monocero'-tis	Unicorn	Hevelius or Bartschius
Mus'-ca	Mus'-cæ	Fly	Bayer
Nor'-ma	Nor'-mæ	Rule	La Caille
Oc'-tans	Octan'-tis	Octant	La Caille
Ophiu'-chus	Ophiu'-chi	Serpent carrier	Ptolemy
Ori'-on	Orio'-nis	Orion	Ptolemy

NAME	GENITIVE	MEANING	PROPOSER
Pa'-vo	Pavo'-nis	Peacock	Bayer
Peg'-asus	Peg'-asi	Winged horse	Ptolemy
Per'-seus	Per'-sei	Perseus	Ptolemy
Phœ'-nix	Phœni'-cis	Phœnix	Bayer
Pic'-tor	Picto'-ris	Painter	La Caille
Pis'-ces	Pis'-cium	Fishes	Ptolemy
Pis'-cis Austra'-lis	Pis'-cis Austra'-lis	Southern fish	Ptolemy
Pup'-pis	Pup'-pis	Stern	La Caille
Retic'-ulum	Retic'-uli	Net	La Caille
Sagit'-ta	Sagit'-tæ	Arrow	Ptolemy
Sagitta'-rius	Sagitta'-rii	Archer	Ptolemy
Scor'-pius	Scor'-pii	Scorpion	Ptolemy
Sculp'-tor	Sculpto'-ris	Sculptor	La Caille
Scu'-tum	Scu'-ti	Shield	Hevelius
Ser'-pens	Serpen'-tis	Serpent	Ptolemy
Sex'-tans	Sextan'-tis	Sextant	Hevelius
Tau'-rus	Tau'-ri	Bull	Ptolemy
Telesco'-pium	Telesco'-pii	Telescope	La Caille
Trian'-gulum	Trian'-guli	Triangle	Ptolemy
Trian'-gulum Austra'-le	Trian'-guli Austra'-lis	Southern triangle	Bayer
Tuca'-na	Tuca'-næ	American goose	Bayer
Ur'-sa Ma'-jor	Ur'-sæ Majo'-ris	Greater bear	Ptolemy
Ur'-sa Mi'-nor	Ur'-sæ Mino'-ris	Lesser bear	Ptolemy
Ve'-la	Velo'-rum	Sails	La Caille
Vir'-go	Vir'-ginis	Virgin	Ptolemy
Vo'-lans	Volan'-tis	Flying (fish)	Bayer
Vulpec'-ula	Vulpec'-ulæ	Fox	Hevelius

It will be seen that there are three kinds of names used; names of animals, names borrowed from mythology, and names of pieces of apparatus.

When and where the constellations were originally designed are questions which have received a great deal of attention and study. This subject can be merely sketched in outline here. The list of 48 constellations given by Ptolemy was by no means original with him, but was simply a slight revision of an earlier list by Hipparchus, date about 140 B.C. And even before his time a fairly full description of the constellations can be found in the poem of Aratus of Soli, date about 280 B.C. But this was simply a versification of an earlier astronomical work by Eudoxus in 370 B.C., and this in turn, as we now know, was not based on observations made by the Greeks, but on astronomical information that was at that time at least two thousand years old. There are three sources of information as to the origin of the constellations: first, the internal evidence from the constellations themselves; secondly, the documentary evidence in

the form of references in the early writings; thirdly, the inscriptions on monuments, tablets, coins, etc., which are continually being discovered. The originators of the constellations naturally portrayed the things with which they were familiar. The elephant, camel, tiger, and crocodile are not represented. This would exclude India and Egypt as possible places of origin. The portion of the sky left unmapped shows the portion of the sky not visible to them. They must thus have lived in about 38° north latitude. In short, all lines of evidence show that the constellations probably originated in the Euphrates valley, and were practically complete as early as 3000 B.C. What we have is thus the Latin form of a Greek digest of very early information. For further information about the origin of the constellations, see—

BROWN, *Primitive Constellations;* Williams and Norgate, London, 1899.

LOCKYER, *The Dawn of Astronomy;* The Macmillan Company, 1894.

MAUNDER, *Astronomy without a Telescope*, Chapter I; "Knowledge" Office, London, 1902.

MAUNDER, *The Oldest Picture-book of All;* The Nineteenth Century Magazine, September, 1900.

III. THE METHODS OF DESIGNATING A STAR

THE oldest, but now obsolete, method of designating a particular star was to describe its position in the constellation. The portion of the sky belonging to a certain constellation was supposed to be covered by a representation or picture of the thing after which the constellation was named. Thus a star might be described as located "in the head of Hercules" or "in the right knee of Bootes" or "in the horn of the bull." Many star charts still give those old pictures in connection with the constellations.

There are four modern methods of designating a star. (1) By name. Hundreds of stars have received individual names, but less than a hundred of these are now in general use. They are usually of Latin, Greek, or Arabic origin, and are either proper names or describe position. For example: Regulus, Spica,

Aldebaran. (2) By means of a letter. In 1603 Bayer introduced the system of designating the stars in a constellation by means of the letters in the Greek alphabet. These are, in order: —

α alpha	η eta	ν nu	τ tau
β beta	θ theta	ξ xi	υ upsilon
γ gamma	ι iota	ο omicron	φ phi
δ delta	κ kappa	π pi	χ chi
ε epsilon	λ lambda	ρ rho	ψ psi
ζ zeta	μ mu	σ sigma	ω omega

The stars were usually lettered in the order of brightness, α being the brightest star, β the next brightest, and so on. When the letters of the Greek alphabet were exhausted, the Roman letters were used. In a few instances the stars were lettered in order of position instead of brightness. The Latin genitive of the constellation name always follows the Greek or Roman letter. For example: α Lyræ, β Geminorum, g Ursæ Majoris. (3) By number. About 1700 Flamsteed introduced the custom of numbering the stars in a constellation. This applies usually to the

fainter stars which had not been lettered, and they were numbered in order of position from west to east. For example: 61 Cygni, 50 Cassiopeiæ. (4) By catalogue number. In the case of some faint stars visible to the naked eye, and nearly all stars visible in a telescope only, the star is designated as having a certain number in a certain catalogue. It is usually the first catalogue in which it occurred or some very well known comprehensive catalogue. For example: Groombridge 966, B.A.C. 4536.

The last three of the four modern methods seldom overlap at present. The brighter stars are usually lettered. Those which are fainter, but still visible to the naked eye, are usually numbered, while telescopic stars are referred to simply by catalogue and number. If a star has a proper name, this is usually given in addition to the Bayer letter.

IV. STAR MAGNITUDES

THE term "magnitude" when applied to a star refers simply to its brightness and not to its volume or mass. Ptolemy arbitrarily graded the stars visible to the naked eye into six classes or magnitudes, the sixth being the faintest and the first the brightest. The reason for having six magnitudes rather than more is not known, unless it is because the eye without the help of instruments is unable to make finer distinctions. After the telescope was invented, the number of magnitudes had to be increased so as to include these faint telescopic stars, but there was no uniformity among different observers in extending the system. As the result, the magnitude of a faint star, as determined by different observers, might differ by even two or three. As measurements became more exact, it also became desirable to subdivide magnitudes.

It had been noticed for some time that, roughly speaking, a star of the first magnitude was about one hundred times as bright as a star of the sixth. In 1850, Pogson proposed to make the $\sqrt[5]{100}$, or 2.512, the uniform ratio between successive magnitudes.

Thus, $b_1 = \sqrt[5]{100}\ b_2$, where b_1 is the brightness of a first magnitude star and b_2 that of a second.

Similarly, $b_2 = \sqrt[5]{100}\ b_3$,

$b_3 = \sqrt[5]{100}\ b_4$ etc.

From these $b_1 = (\sqrt[5]{100})^2 b_3$,

or $b_1 = (\sqrt[5]{100})^4 b_5$,

or $b_3 = (\sqrt[5]{100})^6 b_9$.

Thus, in general, $b_m = (\sqrt[5]{100})^{n-m} b_n$.

Transposing this, $\frac{b_m}{b_n} = (\sqrt[5]{100})^{n-m}$,

$$\log_{10} \frac{b_m}{b_n} = (n-m) \log_{10} \sqrt[5]{100},$$

$$\log_{10} \frac{b_m}{b_n} = 0.4\,(n-m).$$

This formula put into words is: the logarithm of the ratio of brightness equals four tenths of

the difference in magnitude. By means of this formula, if the magnitudes of two stars are given, the ratio of brightness may be computed, and if the ratio of brightness and the magnitude of one star is given, the magnitude of the other may be computed.

EXAMPLE 1. If the magnitude of Mizar (ζ Ursæ Majoris) is 2.4 and the magnitude of Alkor (g Ursæ Majoris) is 4.0, find their ratio of brightness.

$$\log_{10} \text{ratio} = 0.4(4.0 - 2.4) = 0.4(1.6) = 0.64.$$

$$\text{Ratio of brightness} = 4.37.$$

EXAMPLE 2. If a star is 30 times as bright as Polaris (α Ursæ Minoris), magnitude 2.1, find its magnitude.

$$\log_{10} 30 = 0.4(2.1 - x),$$

$$1.477 = 0.84 - 0.4x,$$

$$0.4x = -0.637,$$

$$x = -1.59.$$

The magnitude is -1.59, and this is the magnitude of Sirius (α Canis Majoris).

This definite system of star magnitudes was gradually adopted, and now all star magnitudes are expressed in it. Some star must be con-

sidered to be fundamental, that is, to have a definite unchanging magnitude, and the magnitudes of the other stars must be determined in terms of its magnitude. Polaris (*α* Ursæ Minoris) is usually taken as the fundamental star. By means of photometers all other stars are compared with it, either directly or indirectly, and the ratio of brightness, and thus the magnitude, determined. The work of the Harvard College Observatory in this connection has been particularly noteworthy. Here the actual standard is not Polaris but the mean magnitude of one hundred circumpolar stars of about the fifth magnitude.

In this system of magnitudes, the naked eye can perceive stars of about the sixth magnitude if the air is clear and free from haze. One disadvantage of the system is the fact that there are stars brighter than the first magnitude. A star 2.51 times as bright as one of the first magnitude would be of the 0 magnitude. A star 2.51 times as bright as that would be of the −1 magnitude. Thus for a very bright object a negative magnitude must be used. There is one star which has

a negative magnitude, Sirius (α Canis Majoris) -1.6. On the same scale the sun would have a magnitude of -26.3.

The magnitudes of stars remain remarkably constant. There are only about 500 stars in connection with which a variation in magnitude has been detected, and only about 50 of these are visible to the naked eye. The change in magnitude may be a steady change in one direction, an irregular fluctuation, or a periodic variation. If the fluctuation is irregular, only the limits can be stated. If the variation is periodic, such facts as the limits of the variation and the period may be determined.

V. STAR COLORS

Most of the stars appear to us as white, although in a few cases the star appears to be tinged with color. The following list probably includes the various colors as they appear to the naked eye: greenish white, bluish white, white, yellowish white, orange-white, reddish white. Stars are sometimes said to be yellow, orange, or red, but in every case the white predominates to such an extent that it is really only a tinge of the color in question that is perceived.

As seen through the telescope all the spectrum colors may be noticed, but in every case they are strongly mixed with white.

The causes of these differences in color are differences in temperature and chemical composition.

VI. THE NUMBER OF THE STARS

THE opinion is often expressed that the stars appear almost countless in number. As a matter of fact the total number visible to the naked eye is only about 6,000. Only one-half of these are visible at any one time, and a small amount of haze greatly reduces the number that is visible, particularly near the horizon. Thus on a night which would be considered clear only about 2,000 stars are visible. As was said before, the sixth magnitude is usually considered the limit of visibility to the naked eye. The following table gives the number of stars between each magnitude. The second line of the table gives the values of 4×3^m, where m is the magnitude. The agreement is remarkably close. Expressed in words, the law would be that there are about three times as many stars in each magnitude as in the preceding magnitude.

Magnitude	0	1	2	3	4	5	6
Number of stars		11	28	103	321	1020	2843
4×3^m		12	36	108	324	972	2916

The following list of the twenty brightest stars gives the proper name, the Bayer letter, the magnitude, and the color. The word "(invisible)" indicates that the star is never visible in the United States:—

THE TWENTY BRIGHTEST STARS

Sirius	α Canis Majoris	— 1.6	Bluish white
Vega	α Lyræ	0.1	Bluish white
Arcturus	α Bootis	0.2	Orange
Capella	α Aurigæ	0.2	Yellow
Rigel	β Orionis	0.3	White
——	α Centauri	0.3	White (invisible)
Canopus	α Argus	0.4	Bluish white (invisible)
Procyon	α Canis Minoris	0.5	White
Achernar	α Eridani	0.6	White (invisible)
Betelgeuse	α Orionis	0.9	Red
Altair	α Aquilæ	0.9	Yellow
——	β Centauri	0.9	White (invisible)
Aldebaran	α Tauri	1.1	Red
Antares	α Scorpii	1.2	Red
Pollux	β Geminorum	1.2	Orange
Spica	α Virginis	1.2	White
——	α Crucis	1.3	Bluish white (invisible)
Fomalhaut	α Piscis Australis	1.3	Orange
Regulus	α Leonis	1.3	White
Deneb	α Cygni	1.3	White

VII. THE METHOD OF LOCATING THE STARS AND CONSTELLATIONS

THE method of locating the stars and constellations here advocated is by means of the so-called constellation tracings. Most of the conspicuous constellations contain bright stars which, when connected by lines, form figures, such as a triangle, square, W, sickle, etc., which are easily remembered and quickly recognized. After these tracings have once been learned and noticed, as soon as the eye falls upon that part of the sky, it instinctively runs through the tracing, and the constellation is thus recognized and its stars identified. For convenience in locating them, the 88 constellations have been divided into four groups. The first group consists of 28 conspicuous constellations with tracings. The second group contains the five constellations which are chiefly conspicuous on account of a single very bright star. The third group of 19 comprises the

inconspicuous constellations, while the fourth group contains the 36 constellations which are too far south to be seen at all or well seen from the United States. The following table in four parts gives these four groups of constellations:—

THE 88 CONSTELLATIONS DIVIDED INTO FOUR GROUPS

I. The 28 Conspicuous Constellations with Tracings

Andromeda		Lyra	(triangle and parallelogram)
Aquila		Ophiuchus	
Aries	(triangle)	Orion	(parallelogram)
Auriga	(pentagon)	Pegasus	(square)
Cassiopeia	(W)	Perseus	
Corona Borealis	(semicircle)	Sagitta	(arrow)
Corvus		Sagittarius	
Cygnus	(cross)	Scorpius	(sickle)
Delphinus		Serpens	
Draco		Taurus	(wedge)
Gemini		Triangulum	(triangle)
Hercules		Ursa Major	(big dipper)
Leo	(sickle and triangle)	Ursa Minor	(little dipper)
Libra		Virgo	

II. The 5 Constellations with a single very bright Star

Bootes	Canis Major
Canes Venatici	Canis Minor

Piscis Australis

III. The 19 Inconspicuous Constellations

Aquarius
Camelopardalis
Cancer
Capricornus
Cepheus
Cetus
Coma Berenices
Crater
Equuleus
Eridanus
Hydra
Lacerta
Leo Minor
Lynx
Monoceros
Pisces
Scutum
Sextans
Vulpecula

IV. The 36 Southern Constellations

Antlia
Apus
Ara
Cælum
Carina
Centaurus
Chamæleon
Circinus
Columba
Corona Australis
Crux
Dorado
Fornax
Grus
Horologium
Hydrus
Indus
Lepus
Lupus
Malus
Mensa
Microscopium
Musca
Norma
Octans
Pavo
Phœnix
Pictor
Puppis
Reticulum
Sculptor
Telescopium
Triangulum Aus.
Tucana
Vela
Volans

Charts I. to IV. show the position of the constellations at 9 P.M. during January, April, July, and October. During a following month they would show the position two hours earlier, and during a preceding month two hours later. That is, stars come into the same position two hours earlier after the lapse of a month. The 28 conspicuous constellations and the five with single very bright stars are printed in small capitals, while the inconspicuous constellations are printed in small letters. In order to match the sky, the chart is supposed to be held over the head of an observer facing south. Thus for a convenient hour of the evening, the position of the constellations is given for every month in the year. In order to get the position at any other hour of the evening, only the apparent diurnal rotation of the heavens need be taken account of.

Figures 1 to 24 give the tracings and information about the 28 conspicuous constellations. Andromeda and Perseus, Aries and Triangulum, Libra and Scorpius, Ophiuchus and Serpens, are represented by one figure for each pair. The faint lines represent the tracings.

The arrow points to the north pole of the heavens, and thus indicates for a constellation in any position how the tracing must be held to match the sky. Three symbols are used to represent the stars, depending upon their magnitude: ✦ for stars having a magnitude of 1.4 or brighter; ● for stars having a magnitude between 1.5 and 3.4 inclusive; • for stars having a magnitude of 3.5 or less. The designation of the star and its exact magnitude according to the measurements made at the Harvard College Observatory are stated. The proper name of the star is also given, and its color if not white, and, if variable, the limits of the variation and the period if periodic. At the bottom of each figure the right ascension and declination of the center of each constellation are indicated.[1]

[1] Right ascension and declination are the coördinates in the so-called equator system of coördinates. The fundamental points of this system are the poles of the celestial sphere, that is, the points of no diurnal motion on the celestial sphere. These are the points where the earth's axis produced cuts the celestial sphere. The north pole is located near Polaris (α Ursæ Minoris). The celestial equator is a great circle 90° from the pole. It is the great circle in which the plane of the earth's equator cuts the celestial sphere. The equator runs through the con-

The facts concerning the five constellations with a single very bright star are:—

Bootes—α; name, Arcturus; magnitude, 0.2; color, orange-white.

Canes Venatici—α; name, Cor Caroli; magnitude, 3.3; color, white.

Canis Major—α; name, Sirius; magnitude, —1.6; color, bluish white.

Canis Minor—α; name, Procyon; magnitude, 0.5; color, bluish white. (β Canis Minoris has a magnitude of 3.1 and is fairly conspicuous. The constellation could perhaps have been represented by these two stars better than by a single star.)

Piscis Australis—α; name, Fomalhaut; magnitude, 1.3; color, orange-white.

Of the 19 inconspicuous constellations Cancer and Cepheus are perhaps the most easily recognized. There are two stars in Cepheus

stellations of Pisces, Cetus, Taurus, Orion, Monoceros, Hydra, Sextans, Leo, Virgo, Serpens, Ophiuchus, Aquila, Aquarius. The great circles drawn through the poles and perpendicular to the equator are called hour circles. The starting point or origin of coördinates is the vernal equinox, the point where the sun crosses the equator on March 21. It is located in the constellation of Pisces. Declination is angular distance north or south of the equator; plus when north and minus when south. Right ascension is the portion of the equator between the vernal equinox and the hour circle through the point in question. It is usually expressed in time and runs from 0 to 24 hours.

which catch the eye first and they are quite a little brighter than those near them. These are α (magnitude 2.6) and β (magnitude 3.3). Cancer is noticeable on account of the three stars quite close together which form a little equilateral triangle.

The best method of building up an acquaintance with the stars and constellations from the material here given can only be suggested. Most people know at least two or three constellations. If that is the case, the best method of procedure is to study first the constellations which surround those which are already known. Notice the tracing, determine where the constellation is with reference to those already known, and then try to pick it out among the stars. In this way all of the constellations will become gradually known. If no constellations at all are already familiar to the observer, start with those which are by far the most conspicuous. These are probably Aries, Auriga, Cassiopeia, Leo, Lyra, Orion, Pegasus, Scorpius, Taurus, Ursa Major. Determine from the charts where the constellation is located, observe carefully the tracing, noting particu-

larly the magnitudes of the stars, and then persevere until the constellation is recognized.

For example, if the attempt is to be made to find the constellation of Taurus, fix firmly in mind before going out to observe the sky that the tracing is a V, that all of the stars but one are of about the same magnitude and only moderately bright, and that the one bright star is of the first magnitude and reddish in color. As these facts are sometimes forgotten while observing the sky, it is often convenient to take with one the tracings and a pocket electric lamp for illuminating them.

When a beginning has once been made, progress is usually easy. A single hour's instruction by one familiar with the stars and constellations is sufficient to give a considerable amount of information to a beginner, particularly if the charts and tracings have been carefully studied previously.

Another method advocated by some for building up an acquaintance with the stars and constellations is to start with the fifteen brightest stars. The chief facts about these stars have been given in a previous table. Find

out, by looking up the constellations on the charts, how many of these are visible at the desired time of observation and in what part of the sky they are located. Then persevere as before until these have been recognized, and from these as known points build up an acquaintance with the surrounding stars and constellations. This method of starting with the bright stars can be used to the best advantage when the moon is from three to seven days old. The light of the moon pales out the fainter stars, thus making the bright ones more conspicuous. A perfectly clear moonless night is not the best time to begin observations, as the number of stars visible is confusing.

Some advocate trying to locate the stars and constellations by identifying them when rising or setting. The disadvantages of this method are that the horizon is always more hazy and cloud-covered than the rest of the sky, and, secondly, that it confines the time of observation to a particular hour of the night and is impossible at some times of year.

Any attempt to locate a star or constellation by giving its direction and distance from a known point will be no more successful than to notice its location on a chart.

VIII. THE METHOD OF FURTHER STUDY

THE charts, figures, and information given above can serve only as a guide in taking the first steps in learning the stars and constellations. Further knowledge is both useful and pleasant, and to gain it the reader must be referred to the numerous books bearing on the subject. Some of these books will be indicated here.

ALLEN, *Star-names and their Meanings;* G. E. Stechert, 1899, is a veritable mine of information. It gives the meaning of the names used in connection with the stars and constellations, numerous extracts from the writings where these names were used, and the more important facts such as magnitude, color, etc., about the chief stars in each constellation. It is a compendium of information, but not a book to be read through as a whole.

There are two books, MARTIN, *The Friendly Stars;* Harper and Brothers, 1907,

and SERVISS, *Astronomy with the Naked Eye;* Harper and Brothers, 1908, which attempt to put in readable and attractive form the facts concerning the stars and constellations. The last-named book also contains star charts, giving the position of all stars down to the sixth magnitude. These are the two books to recommend whenever a book giving a popular presentation of the subject is desired.

Among the modern up-to-date star atlases may be mentioned:—

BALL, *A Popular Guide to the Heavens;* George Philip & Son, London, 1905.

KLEIN, *Star Atlas;* E. & J. B. Young & Co., New York, 1901.

PECK, *The Observer's Atlas of the Heavens;* Gall & Inglis, London, 1898.

UPTON, *Star Atlas;* Ginn & Company, 1896.

MESSER, *Stern-Atlas für Himmelsbeobachtungen;* K. L. Ricker, Leipzig, 1902.

A star atlas is absolutely essential to one who desires to add to his knowledge of the stars and constellations. The star charts in these atlases represent all the constellations with their boundaries, and give the location of all stars visible to the naked eye. In addition

much information is given concerning star magnitudes, double stars, variable stars, star colors, etc. The meaning of the names, however, and the historical side of the subject are usually not treated. If it is desired to identify an unknown star, the best method is to estimate its magnitude carefully, and note its location with reference to several known stars or constellations. A chart of this portion of the sky may then be consulted, and the unknown star can usually be readily identified and the constellation to which it belongs determined. If it is desired to locate an inconspicuous star or constellation, the best method is to note on the appropriate chart its location with reference to several easily identified stars or constellations. On turning to the sky the inconspicuous object can usually be readily located and identified. In this way, by means of star atlases, one's information may be indefinitely extended.

Such atlases as ARGELANDER'S *Atlas des Nördlichen Gestirnten Himmels* (2d edition by Küstner, Bonn, 1899), PETERS'S *Celestial Charts* (published at Canton, N. Y.),

and the *Uranometria Argentina* are useful only in connection with the telescope when it is desired to identify all the stars, perhaps even to the ninth or tenth magnitude, within a very small area such as the field of view of the telescope.

Lists of the constellations, the stars visible to the naked eye, colored stars, variable stars, etc., can also be found in CHAMBERS'S *Handbook of Descriptive and Practical Astronomy* (The Clarendon Press, 1890) and VALENTINER, *Handwörterbuch der Astronomie* (Breslau, 1901).

If the coördinates of a star, right ascension, and declination are desired, they may be found for a small selected list of stars in *The American Ephemeris and Nautical Almanac*, published each year at Washington, or in the corresponding year books of the English, French, and German governments. AMBRONN, *Sternverzeichnis* (Julius Springer, Berlin, 1907) also contains the coördinates of all stars (7796 in all) which are above the 6.5 star magnitude. Such information, however, is desired not by the observer who is locating an object by

means of the stars, but by the computer who is reducing the observations.

The following list contains other valuable books on the stars and constellations:—

BURRITT, *Atlas designed to illustrate the Geography of the Heavens;* New York, 1835.

COTTAM, *Charts of the Constellations;* London, 1889.

DIEN, *Atlas Céleste;* Paris, 1869.

GORE, *Star Groups;* Crosby Lockwood & Sons, London, 1891.

HEIS, *Atlas Cœlestis Nouvus;* Cologne, 1872.

HILL, *The Stars and Constellations;* Funk & Wagnalls Company, New York, 1894.

JEANS, *Handbook for Finding the Stars;* London, 1888.

JOHNSTON, *School Atlas of Astronomy* (revised by Grant); G. P. Putnam's Sons, New York.

MAUNDER, *Astronomy without a Telescope;* London, 1902.

PECK, *The Constellations and how to find them;* Gall & Inglis, London.

PORTER, *The Stars in Song and Legend;* Ginn & Company, New York, 1902.

PROCTOR, *Half-hours with the Stars;* G. P. Putnam's Sons, 1875.

SERVISS, *Pleasures of the Telescope;* D. Appleton & Company, New York, 1905.

SERVISS, *Astronomy with an Opera-glass;* D. Appleton & Company, New York, 1906.

YOUNG, *Uranography,* in his *Elements of Astronomy;* New York, 1890.

The star atlases of Burritt, Heis, and Dien are particularly interesting, as they give great prominence to the constellation figures, as was the case with all the older atlases.

Printed in the United States of America.

CHART I.

January 1st, 9 p.m.

Dec. 1st, 11 p.m.
Feb. 1st, 7 p.m.
March 1st, 5 p.m.

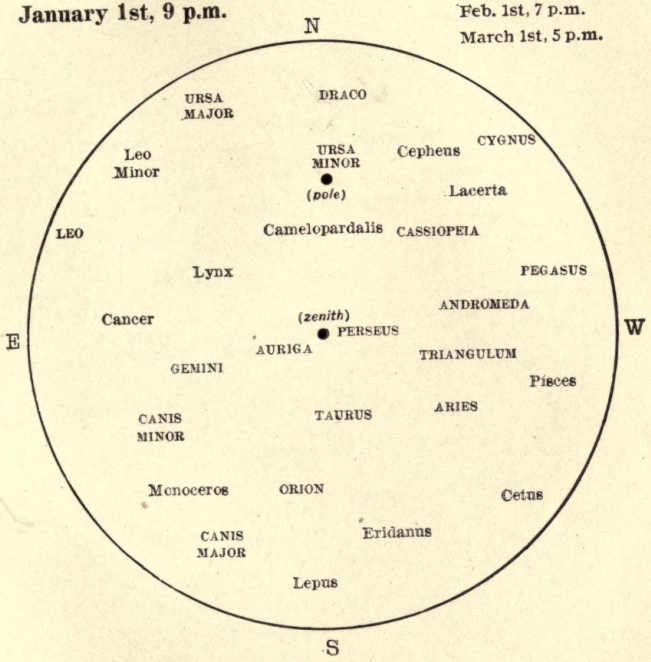


CHART II.

April 1st, 9 p.m.

March 1st, 11 p.m.
May 1st, 7 p.m.

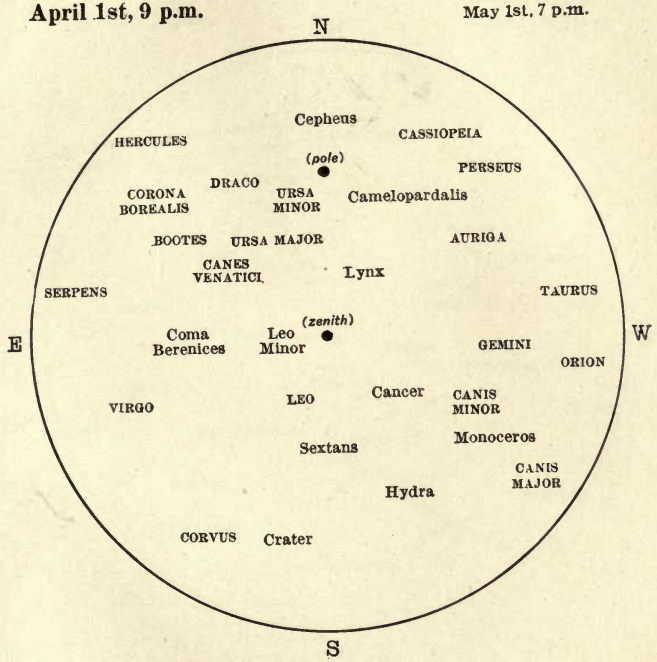


CHART III.

July 1st, 9 p.m.

June 1st, 11 p.m.
August 1st, 7 p.m.

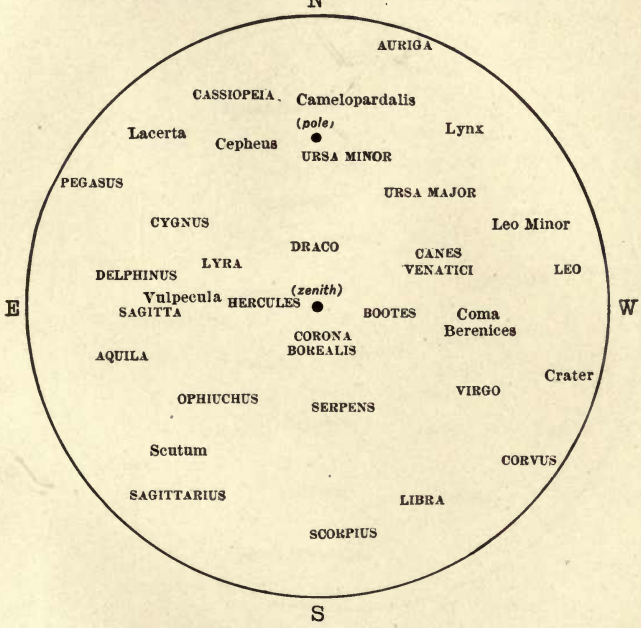
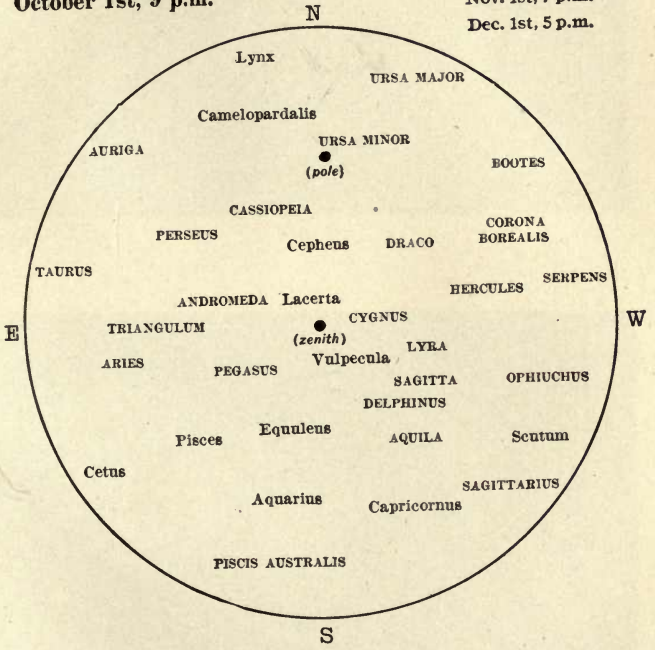


CHART IV.

October 1st, 9 p.m.

Sept. 1st, 11 p.m.
Nov. 1st, 7 p.m.
Dec. 1st, 5 p.m.



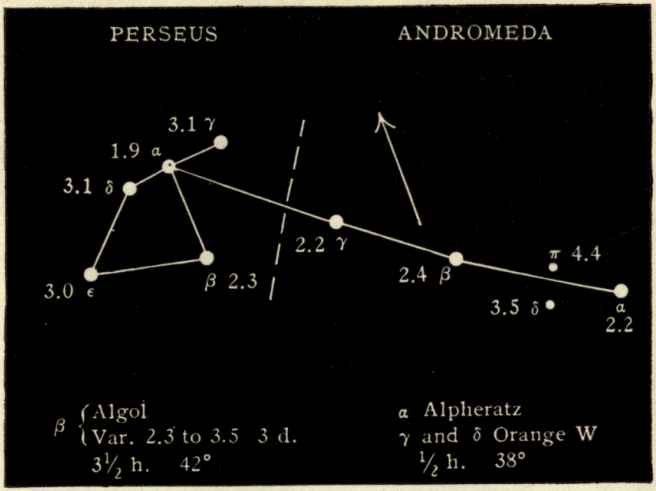

PERSEUS
ANDROMEDA
3.1 γ
1.9 α
3.1 δ
2.2 γ
π 4.4
2.4 β
3.0 ε
β 2.3
3.5 δ
α
2.2
β Algol
Var. 2.3 to 3.5 3 d.
3½ h. 42°
α Alpheratz
γ and δ Orange W
½ h. 38°

FIG. 1

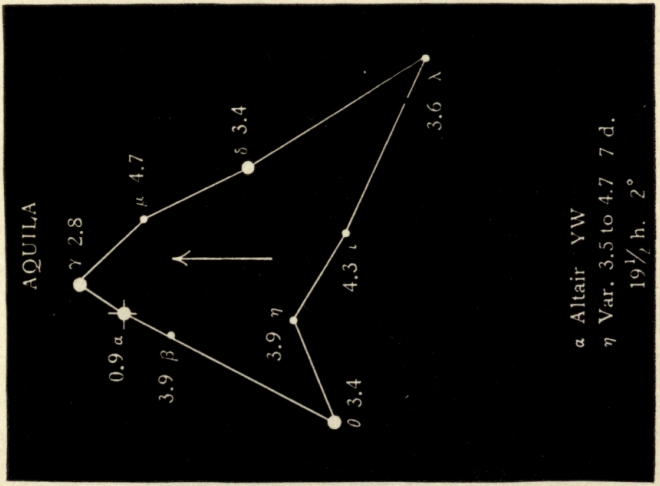
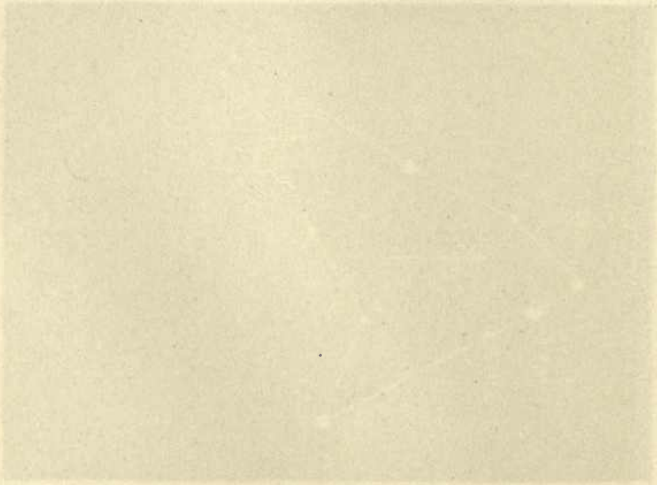

AQUILA
γ 2.8
μ 4.7
δ 3.4
3.6 λ
4.3 ι
0.9 α
3.9 β
3.9 η
θ 3.4
α Altair VW
η Var. 3.5 to 4.7 7 d.
19½ h. 2°

FIG. 2



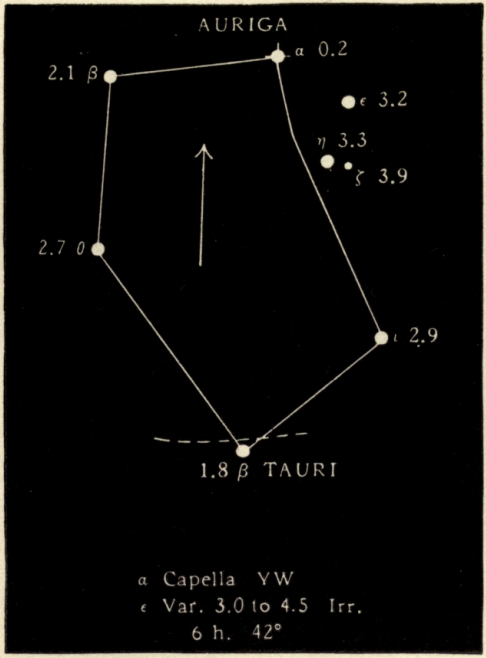

AURIGA
α 0.2
2.1 β
ε 3.2
η 3.3
ζ 3.9
2.7 θ
ι 2.9
1.8 β TAURI
α Capella YW
ε Var. 3.0 to 4.5 Irr.
6 h. 42°

FIG. 4

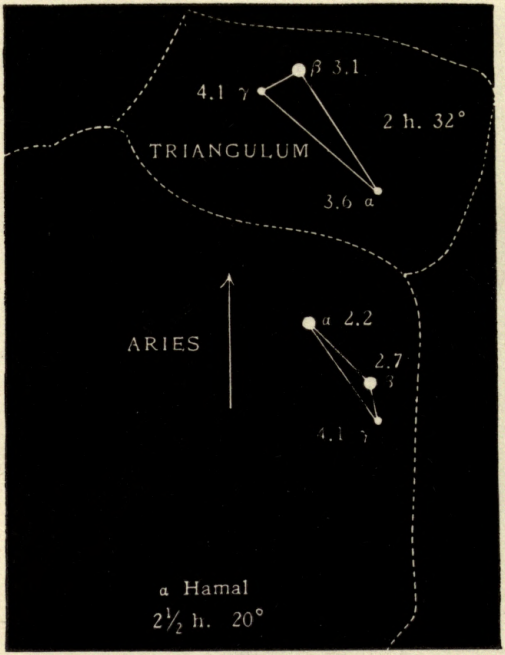

β 3.1
4.1 γ
2 h. 32°
TRIANGULUM
3.6 α
α 2.2
ARIES
2.7
4.1 γ
α Hamal
2½ h. 20°

FIG. 3

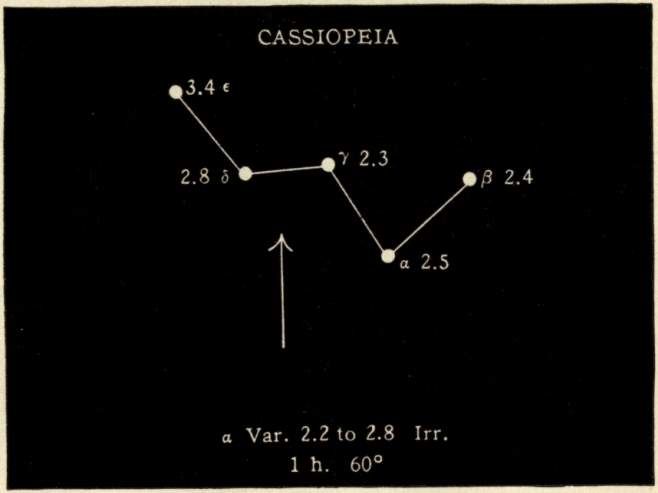

CASSIOPEIA
3.4 ε
2.8 δ
γ 2.3
β 2.4
α 2.5
α Var. 2.2 to 2.8 Irr.
1 h. 60°

FIG. 5

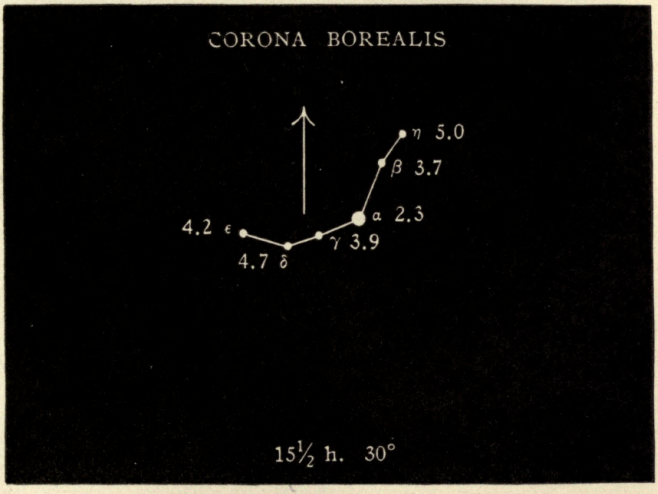

CORONA BOREALIS
η 5.0
β 3.7
α 2.3
4.2 ε
γ 3.9
4.7 δ
15½ h. 30°

FIG. 6

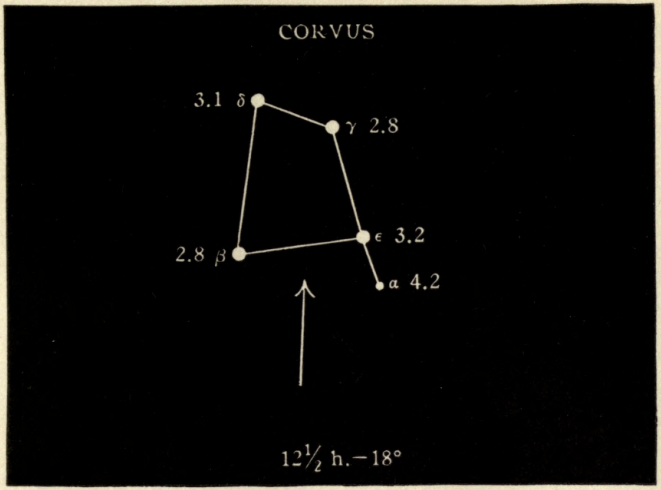

CORVUS
3.1 δ
γ 2.8
ε 3.2
2.8 β
α 4.2
12½ h. −18°

FIG. 7

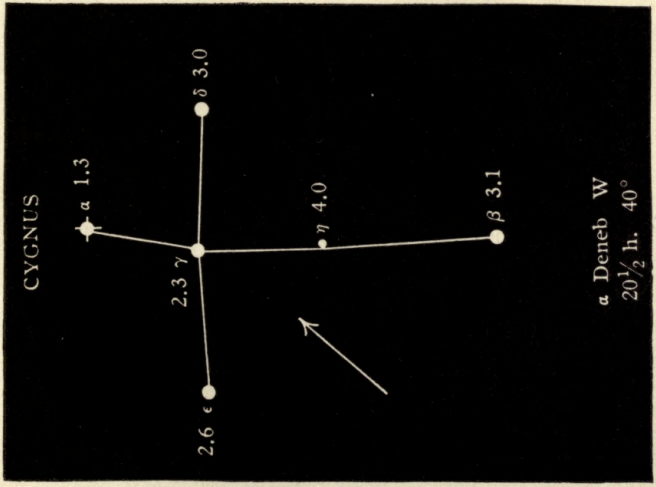

CYGNUS
α 1.3
δ 3.0
2.3 γ
η 4.0
β 3.1
2.6 ε
α Deneb W
20½ h. 40°

FIG. 8

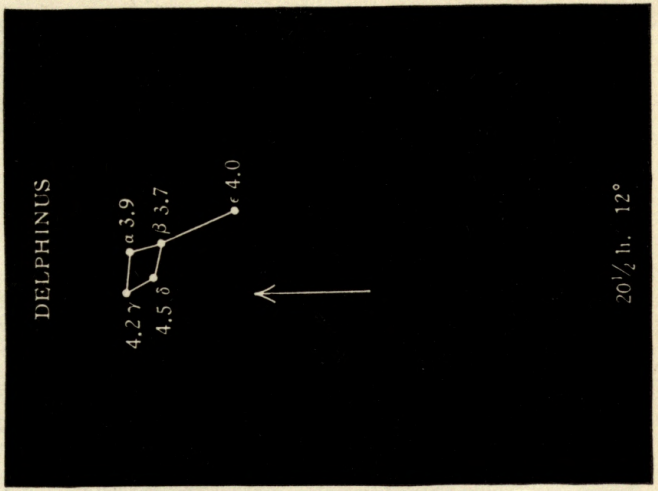

DELPHINUS
α 3.9
β 3.7
ε 4.0
4.2 γ
4.5 δ
20½ h. 12°

FIG. 9

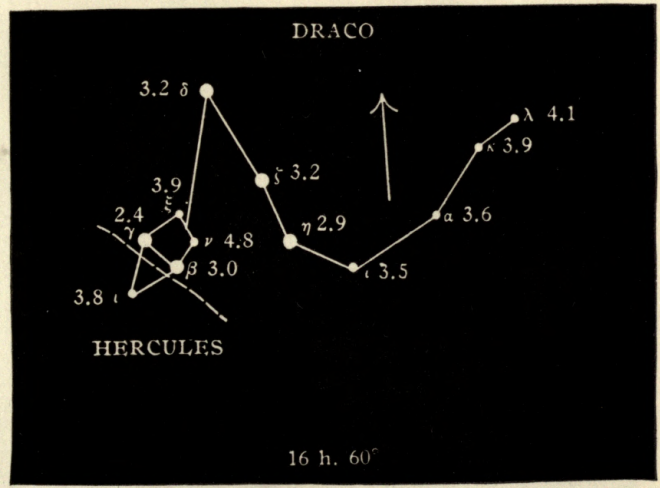
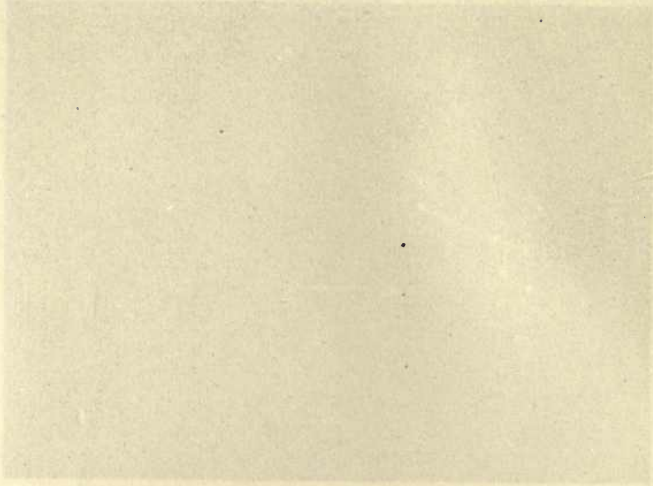
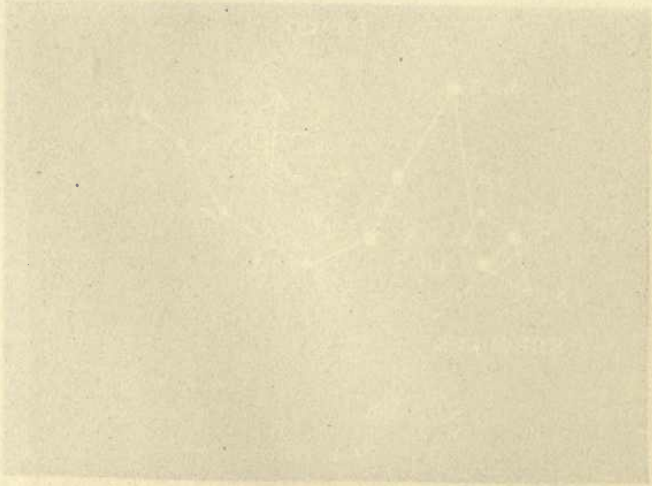

DRACO
3.2 δ
λ 4.1
κ 3.9
ζ 3.2
3.9
2.4
γ
ν 4.8
η 2.9
α 3.6
β 3.0
ι 3.5
3.8 ι
HERCULES
16 h. 60°

FIG. 10





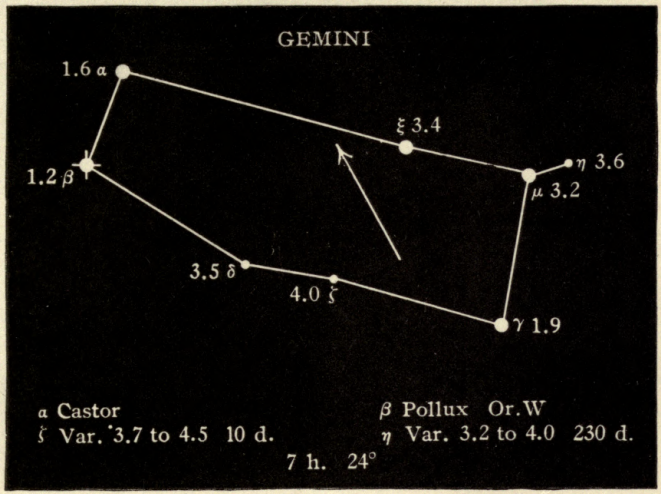

GEMINI
1.6 α
ξ 3.4
η 3.6
1.2 β
μ 3.2
3.5 δ
4.0 ζ
γ 1.9
α Castor
β Pollux Or.W
ζ Var. 3.7 to 4.5 10 d.
η Var. 3.2 to 4.0 230 d.
7 h. 24°

FIG. 11

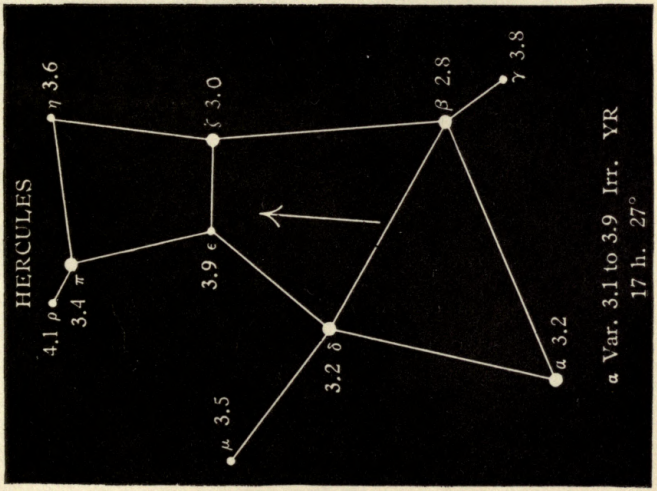

HERCULES
η 3.6
ζ 3.0
β 2.8
γ 3.8
3.9 ε
3.4 π
4.1 ρ
3.2 δ
α 3.2
μ 3.5
α Var. 3.1 to 3.9 Irr. YR
17 h. 27°

FIG. 12

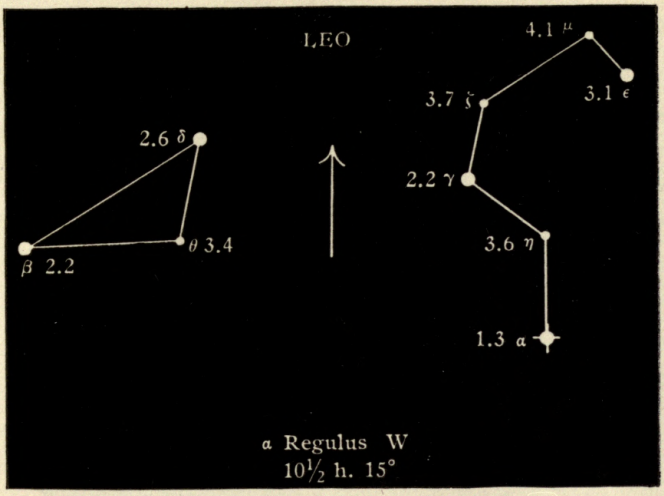

LEO
4.1 μ
3.7 ζ
3.1 ε
2.6 δ
2.2 γ
θ 3.4
3.6 η
β 2.2
1.3 α
α Regulus W
10½ h. 15°

FIG. 13

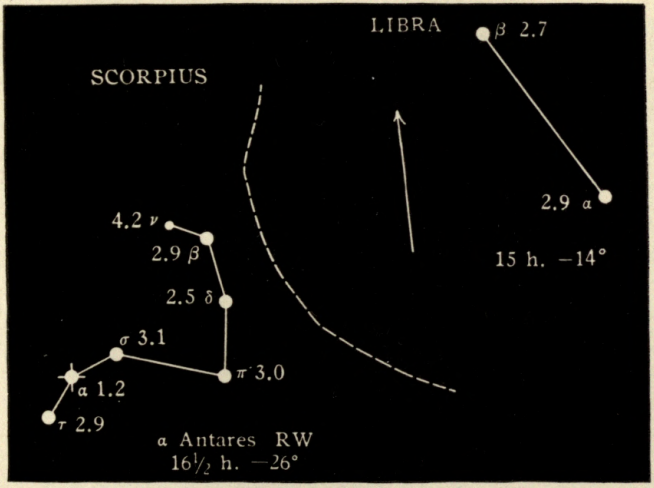
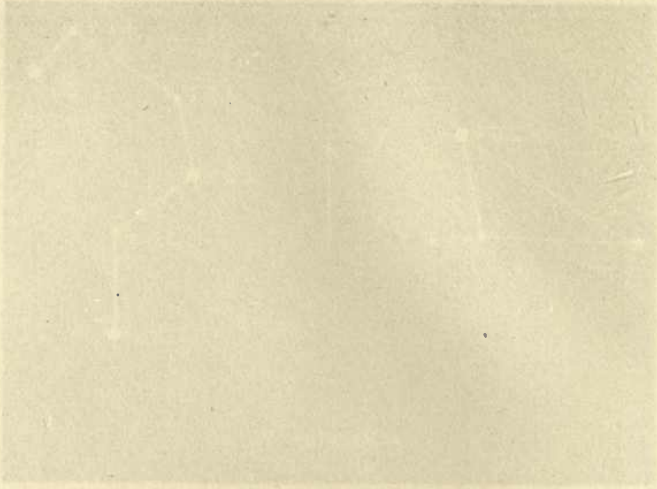
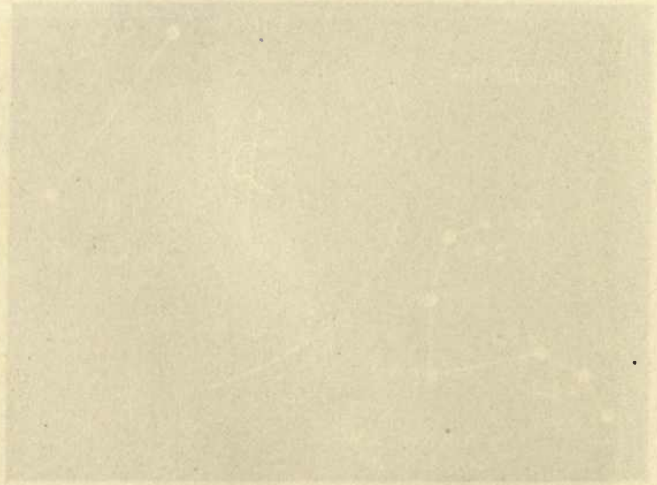

LIBRA
β 2.7
SCORPIUS
2.9 α
4.2 ν
2.9 β
15 h. −14°
2.5 δ
σ 3.1
π 3.0
α 1.2
τ 2.9
α Antares RW
16½ h. −26°

FIG. 14





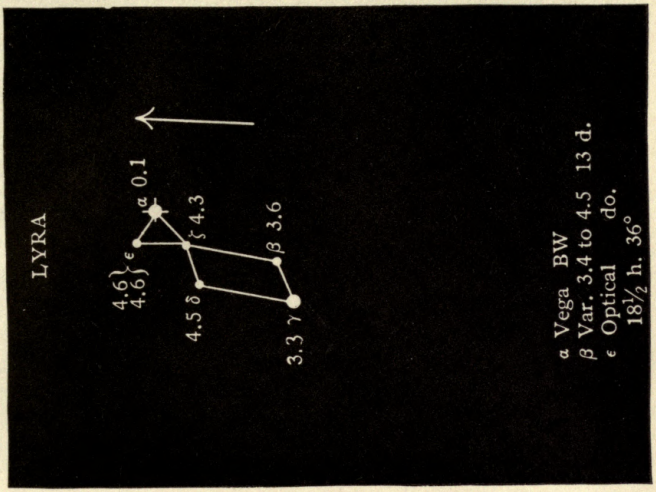

LYRA
α 0.1
ζ 4.3
β 3.6
4.6
4.6
ε
4.5 δ
3.3 γ
α Vega BW
β Var. 3.4 to 4.5 13 d.
ε Optical do.
18½ h. 36°

FIG. 15

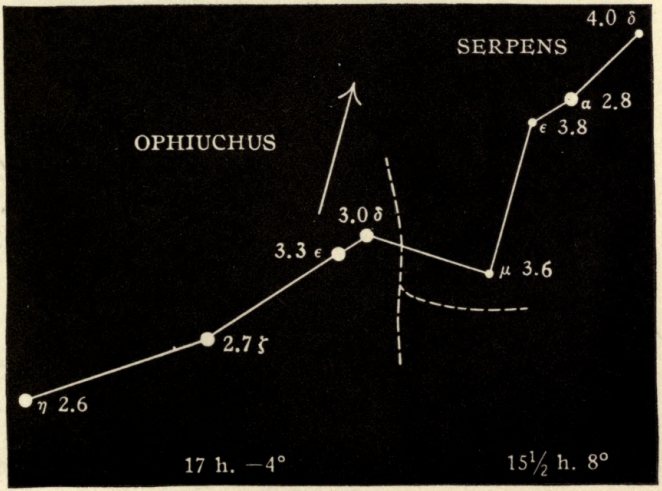

SERPENS
4.0 δ
α 2.8
ε 3.8
OPHIUCHUS
3.0 δ
3.3 ε
μ 3.6
2.7 ζ
η 2.6
17 h. −4°
15½ h. 8°

FIG. 16

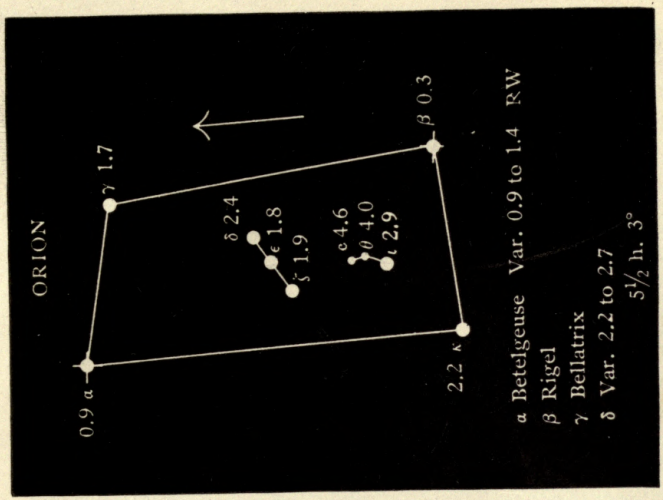

ORION
γ 1.7
β 0.3
δ 2.4
ε 1.8
ζ 1.9
c 4.6
θ 4.0
ι 2.9
0.9 α
2.2 κ
α Betelgeuse Var. 0.9 to 1.4 RW
β Rigel
γ Bellatrix
δ Var. 2.2 to 2.7
5½ h. 3°

FIG. 17

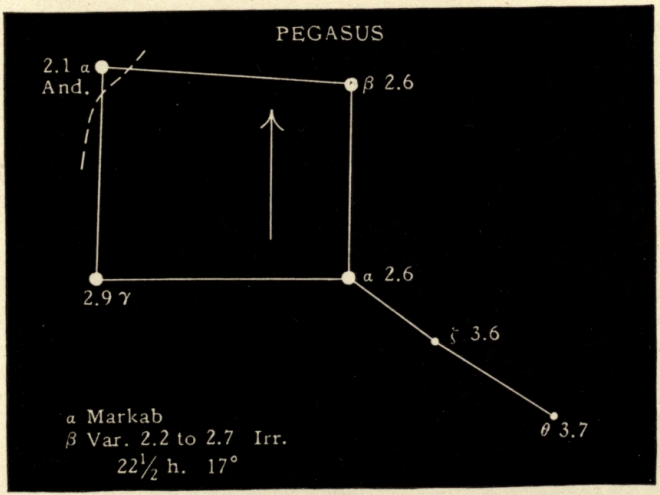
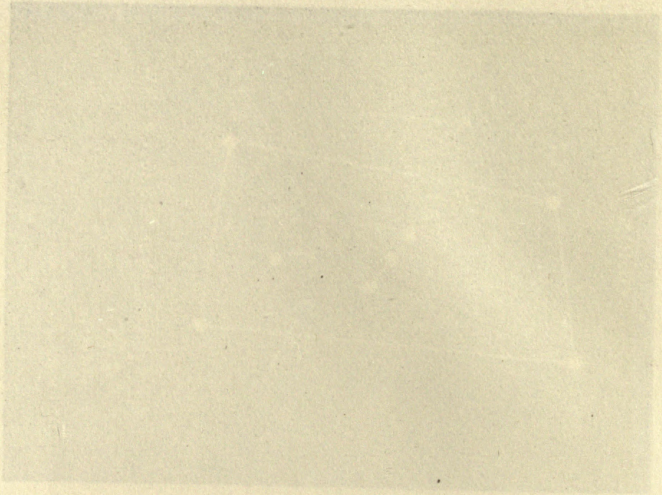
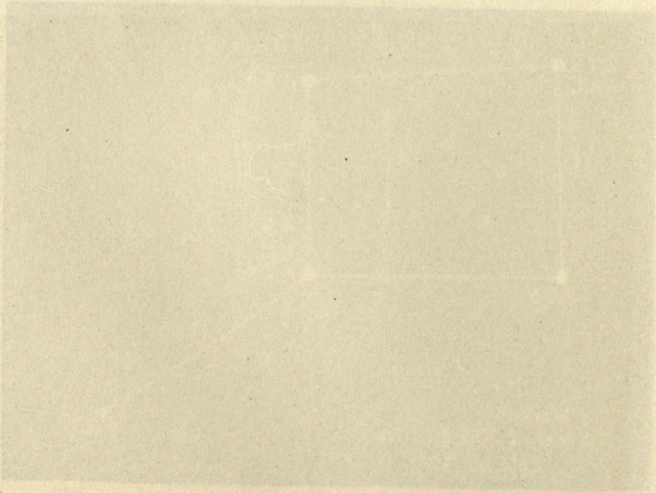

PEGASUS
2.1 α And.
β 2.6
α 2.6
2.9 γ
ζ 3.6
θ 3.7
α Markab
β Var. 2.2 to 2.7 Irr.
22½ h. 17°

FIG. 18





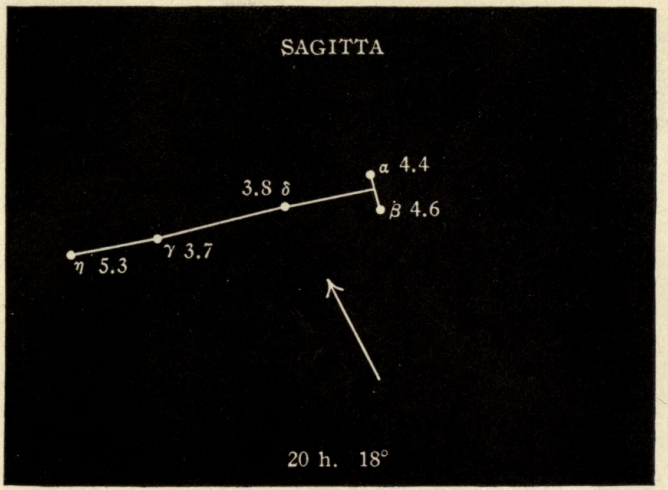

SAGITTA
α 4.4
3.8 δ
β 4.6
γ 3.7
η 5.3
20 h. 18°

FIG. 19

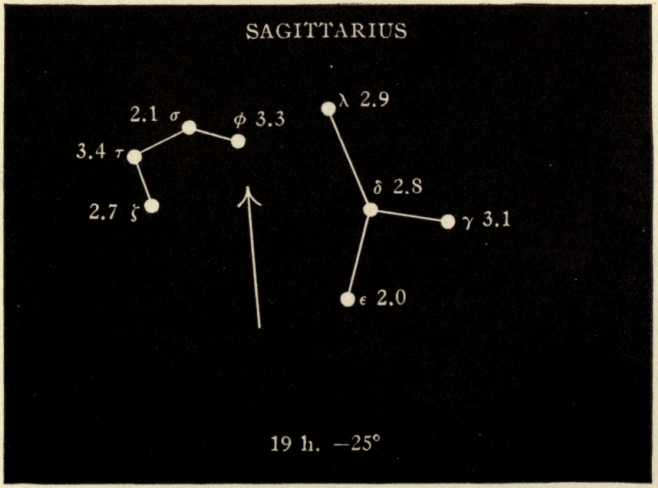

SAGITTARIUS
λ 2.9
2.1 σ
φ 3.3
3.4 τ
δ 2.8
γ 3.1
2.7 ζ
ε 2.0
19 h. −25°

FIG. 20

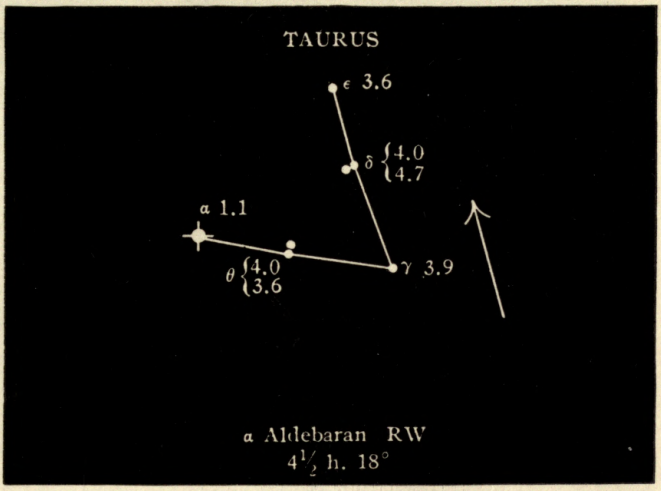

TAURUS
ε 3.6
δ 4.0
4.7
α 1.1
θ 4.0
3.6
γ 3.9
α Aldebaran RW
4½ h. 18°

FIG. 21

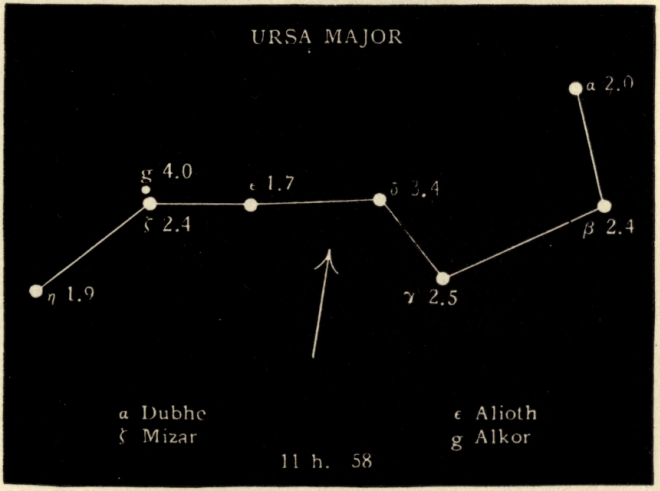
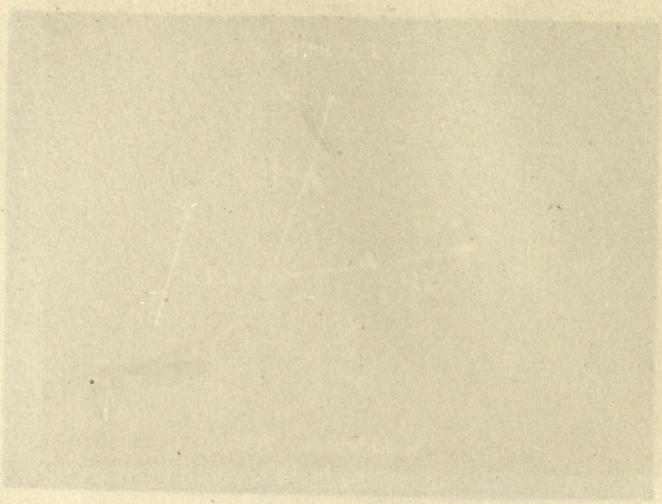
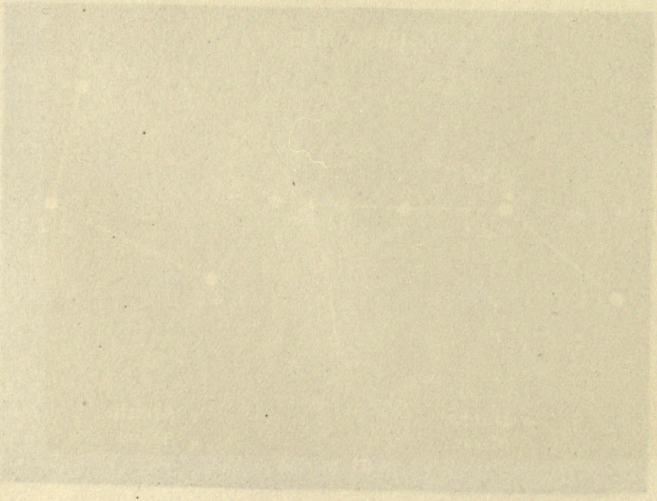

URSA MAJOR
α 2.0
g 4.0
ε 1.7
δ 3.4
ζ 2.4
β 2.4
η 1.9
γ 2.5
α Dubhe
ζ Mizar
ε Alioth
g Alkor
11 h. 58

FIG. 22





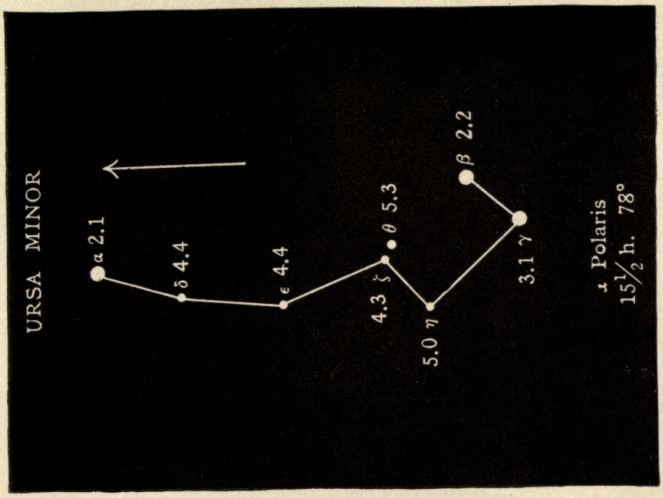

URSA MINOR
α 2.1
δ 4.4
ε 4.4
4.3 ζ
θ 5.3
5.0 η
3.1 γ
β 2.2
α Polaris
15½ h. 78°

FIG. 23

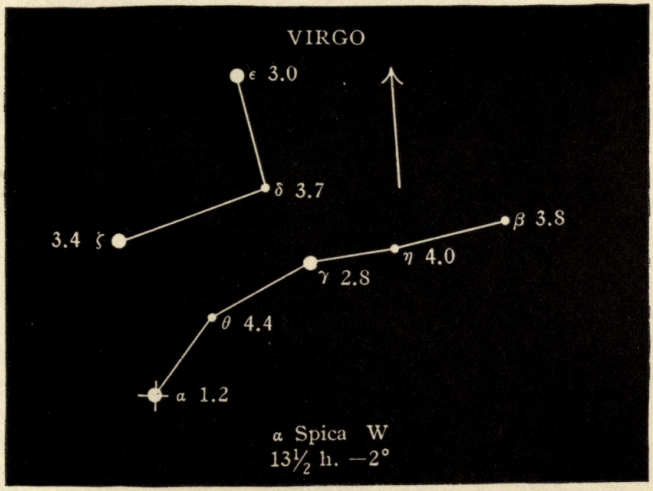

VIRGO
ε 3.0
δ 3.7
3.4 ζ
β 3.8
η 4.0
γ 2.8
θ 4.4
α 1.2
α Spica W
13½ h. −2°

FIG. 24